Dissertation

LIFE HISTORY AND BEHAVIOR OF DASCYLLUS ALBISELLA GILL, A POMACENTRID REEF FISH

by

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SECTION I

INTRODUCTION

Fishes of the family Pomacentridae are most abundant in calm tropical or subtropical waters where they are associated with various kinds of shelter. Most species inhabit crevices or holes in the bottom but some form commensal relationships. Amphiprion sp. are well known because they associate with large sea anemones, and Dascyllus sp. are known as coral fishes because they associate with various species of corals.

Dascyllus albisella Gill is a reef fish endemic to Hawaii. It is a small, deep-bodied fish reaching a maximum length of about 5 inches. Juveniles are usually black with a white spot on each side and a turquoise spot on the head. Adults are either pale or dark, the white spots fading with age.

Adults and juveniles occur both on inshore and offshore reefs in aggregations of a few to over 100 individuals. They are usually associated with coral heads into which they retreat when alarmed. Adults spawn on the bottom and care for the eggs until they hatch. Like many Hawaiian fish species, the larvae are pelagic and the juveniles return to the bottom at an early age.

Preliminary observations showed that juveniles were closely associated with ramose coral heads located on particular parts of reefs. On the other hand, adults were most often associated with glomerate coral heads either on inshore or offshore reefs, and did not seem as dependent on shelter as juveniles. However, the environmental conditions associated with their distribution as well as most essential details of the life history remained unknown.

The objectives of this investigation were twofold. The first objective was to investigate the life history and habits of the species, including reproduction, growth and food. The second objective was to associate distribution with physical and biological influences in the environment, including temperature, salinity, water movement and predation. It was hoped that this study would not only provide details of the life history of the fish, but would also show the interaction between environmental factors that determine the distribution of the fish.

SECTION II

LIFE HISTORY

2.1 DISTRIBUTION

Dascyllus albisella Gill, a species of coral reef fish, occurs throughout the main Hawaiian Islands and possibly exists in the other islands of the chain extending to the northwest. Its closest relative, Dascyllus trimaculatus (Rüppell), is widely distributed throught the Indo-Pacific region and may approach Hawaii at Johnston Island, some 660 miles to the southwest.

The fish, common around the island of Oahu, is found both in shallow bays and off exposed shores as well as in sheltered reef areas. It is particularly abundant in Kaneohe Bay on the windward shore of Oahu, where it occurs along the sloping sides of the shallow reef platforms and around the masses of living coral found in deeper areas in portions of the bay. Although the adults are free-living, they are found mainly in the vicinity of coral of the genus Porites. They usually do not develop an association with a particular coral head, but roam freely over the surface of beds of coral, in which they take shelter when sufficiently disturbed. Apparently, they also live in exposed waters outside of Kaneohe Bay, but their distribution in this habitat has not been studied.

Adults are very common in the exposed waters beyond the surf zone off the Waikiki Beach and Ala Moana areas on the leeward side of the island, where they form aggregations numbering from a few to several hundred fish. The aggregations are associated mostly with patches of Porites coral, varying in size from a few square feet to an acre or larger. They occur at depths ranging from 20 to at least 180 feet, but are most numerous at depths of 50 to 80 feet. The limit of the distribution of fish in a seaward direction is determined most likely by the distribution of coral, and in a shoreward direction, by the increasing force of the surges found there.

Juveniles and adults are found in both shallow and deep water. However, since the young are more closely associated with ramose coral heads, their distribution depends in large part on the distribution of the coral. In addition to occupying the deeper waters where adults are found, juveniles are also abundant on shallow reef flats where they are most numerous in spring and early summer. Like adults, they are also occasionally found around piles of rocks, wharf pilings and in other sheltered locations.

2.2 REPRODUCTION

2.2.1 Materials and Methods

Fish were collected during 1959 and 1960 by spearing, trapping and poisoning, and their gonads were examined to learn more about the reproductive habits of the species. Entire ovaries, or portions of ovaries, were weighed on a chainomatic balance to thousandths of a gram after excess moisture had been removed. When egg counts were made, portions of the ovaries were weighed and the number of eggs they contained were counted. The weight of the remainder of the ovaries was then determined and the total number of eggs was calculated by dividing the weight of the aliquot into the total weight and multiplying by the number of eggs.

The sizes of eggs in various stages of maturity were measured to hundredths of a millimeter by using a microscope equipped with an ocular micrometer. Aliquots from different areas of the ovaries were mixed together to minimize possible differences in the ratio of various egg size groups. Numbers of spawnable eggs in the ovaries were calculated by multiplying the number of mature eggs in an aliquot by the number of aliquots in the pair of ovaries (based on weight as expressed in the preceding paragraph.)

2.2.2 Time and Duration of Spawning

Information on the spawning cycle may be gained from a study of seasonal variation in mean gonad weight (Tester, 1951). The relatively rapid development of gonads during the onset of the breeding season leads to a relative increase of gonad weight in relation to body weight of the fish. When eggs are spawned, the ratio decreases. Thus a peak in the mean ratio can be expected to coincide with the mid-part of the spawning season.

Figure 1 shows the monthly average ratio of gonad weight to body weight based on a total of 254 adult Dascyllus albisella captured during 1959. The ratio increased slightly between January and February, and then rose more rapidly to a peak in June. The ratio decreased slightly during July and August, and then declined rapidly. The figure indicates that a spawning peak took place during June or July with a period of maximum spawning from May to August. A low value of the ratio during other months of the year does not necessarily preclude the possibility of a small amount of spawning. That spawning did take place during the winter months is indicated by the presence of small numbers of fish with ovaries containing ripe eggs, and by the presence of very small juveniles collected at Coconut Island during January of 1961 (see Figure 20).

Helfrich (1958) conducted a similar analysis on gonads of the maomao, Abudefduf abdominalis (Quoy and Gaimard). His results show a peak of spawning activity that coincides with that for Dascyllus albisella, but the peak falls off more rapidly during the months of July and August. There was a similar reduced activity during the winter, although

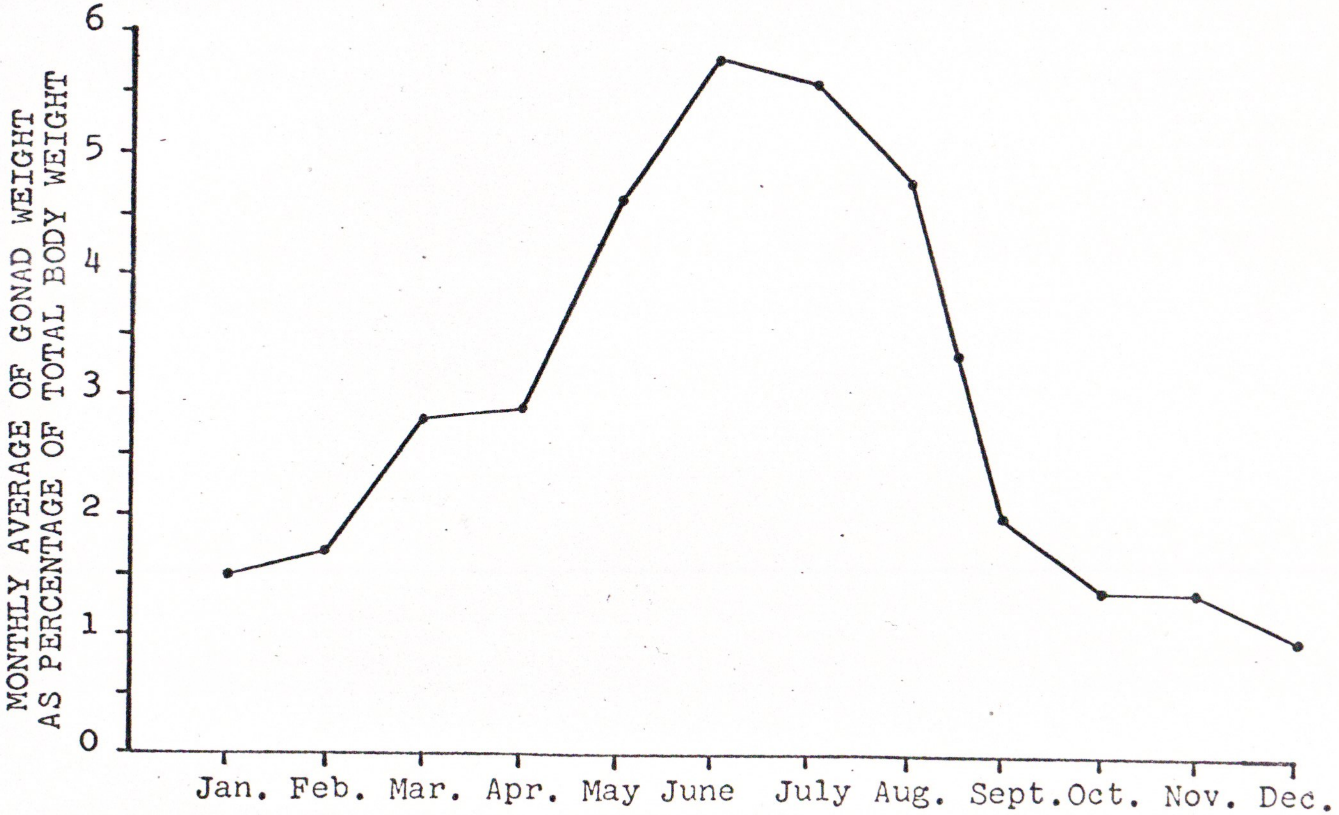


Figure 1. Ovary weight expressed as a percentage of total body weight of 254 female *Dascyllus* collected during 1959.

the ratio in *A. abdominalis* reached the lowest point in November, while that for *D. albisella* occurred in December.

Garnaud (1957) has shown that a pair of fish of the closely related species, *Dascyllus trimaculatus*, spawned three times each month during a four month period in an aquarium at the Musée Oceanographique de Monaco. Although his observations were interrupted for several months, they were sufficient to show a reduced period of egg laying during the autumn. He stated, furthermore, that most pomacentrids spawn frequently and lay numerous eggs.

Verwey (1930) reported that another pomacentrid, *Amphiprion percula* (Lacepede), spawned 14 times between April and November in the Onrust Aquarium, Batavia. He observed the greatest spawning activity during June through August.

The observations on these other species conform with a conclusion that *Dascyllus albisella* may spawn throughout the year but has a period of maximum spawning during the summer months.

During the course of gonad analyses, it became apparent that none of the fish examined from Kaneohe Bay had mature ovaries, although all of the fish were captured in traps during the height of the spawning season. This seemed unusual, because the physical and biological factors initiating spawning should be as applicable in Kaneohe Bay as elsewhere. An explanation emerges from an examination of length frequency distributions of fish from Kaneohe Bay and from Waikiki.

The length frequency distributions shown in Figure 2 result from grouping fish lengths in 5 mm. intervals. The fish captured at Waikiki were significantly larger ($P< 0.01$) than the fish from Kaneohe Bay, and the distribution was more symmetrical. The fish from the latter area were much more variable in size, ranging from 75 to 120 mm. in fork length, and the major portion of the size distribution (72%) was below the mode of 105 mm.

In the Waikiki collections, very few of the fish smaller than 110 mm. had mature gonads. It seems likely that Dascyllus albisella reaches sexual maturity at approximately this size, although the estimate is not exact because of the small numbers of fish available for study. Thus the majority of the fish caught in Kaneohe Bay were probably too small to have attained sexual maturity.

The reason for the differences in size between fish from the two areas is not known. Since food is plentiful in Kaneohe Bay, fish should grow to sizes comparable to those at Waikiki. It is possible that traps are in some way selective and that sexually mature fish are not caught

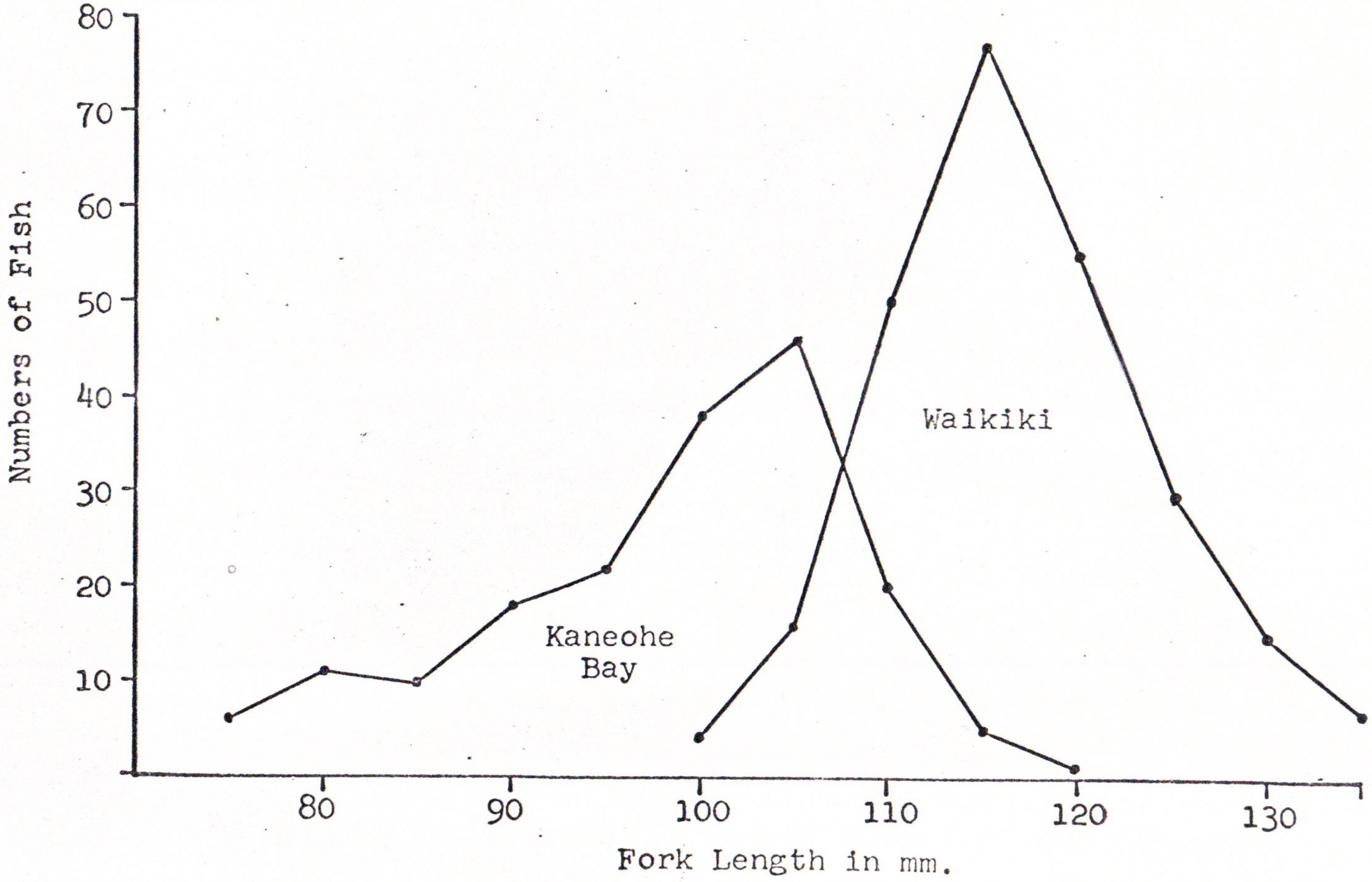


Figure 2. Length frequency of female *Dascyllus albisella* captured at Waikiki and Kaneohe Bay during 1959 and 1960.

because some behavioral activity of the fish in relation to nesting might prevent them from entering. However, many other species of fish in the gravid condition are commonly taken in traps in the same areas. Since spawning activity was never seen in Kaneohe Bay, despite many hours of searching, it is possible that the fish spawn only in parts of the bay which were not covered by observation or trapping, or in the deeper waters outside the bay. It is possible that depth might be a factor, since adult _Dascyllus_ _albisella_ off Waikiki were not seen to spawn to any great extent at depths shallower than 40 feet.

2.2.3 _Fecundity_

It is difficult to determine the total annual egg production of a female because an individual probably spawns more than once during the year. The presence of fishes in various stages of ovarian development throughout the year makes it difficult to trace a progressive increase in egg diameters because of small numbers of fish available for this study. The mature ovary of this species (Figure 3) contains two distinct modal groups of developing eggs resembling those of the maomao, _Abudefduf_ _abdominalis_, (Helfrich, 1958), and the aholehole, _Kuhlia_ _sandvicensis_, (Tester and Takata, 1953). However, spent ovaries with residual eggs in a particular stage of development that allowed the latter authors to "suggest that one aholehole

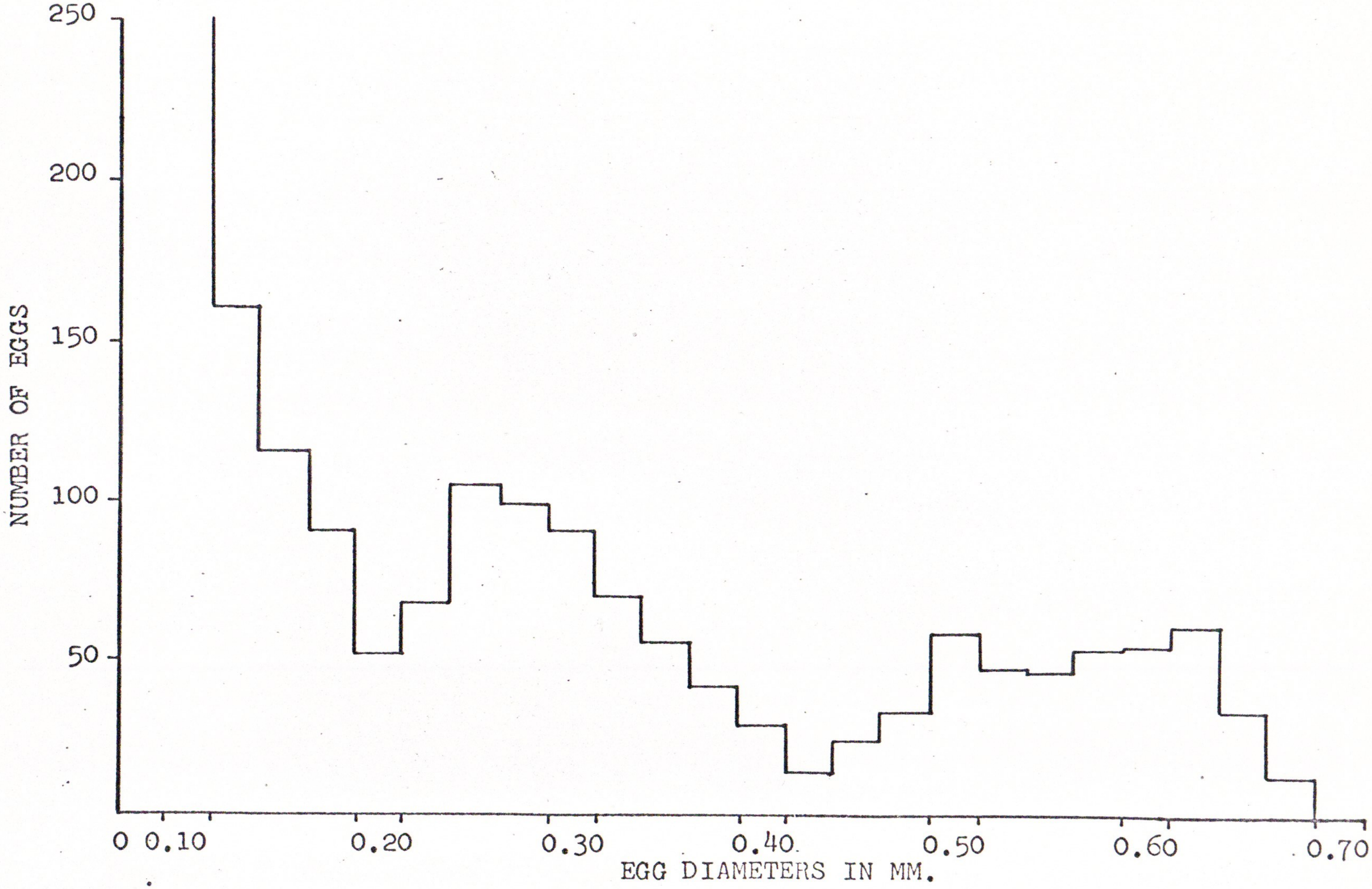


Figure 3. Frequency distribution of egg diameters for a typical ripe ovary.

may ripen and spawn two or more batches of eggs during the course of the year" were not found in Dascyllus albisella.

Although it is not possible to determine total egg production during the year, it is possible to determine the number of eggs that females can spawn at any one time. This was accomplished by counting the numbers of ripe or nearly ripe eggs in portions of the ovaries of gravid female fish. Such eggs are easily distinguished from others in the ovary because of their large size (0.8 - 1.0 mm.), translucent whiteness, the presence of conspicuous oil globules and the fact that they are free in the lumen of the ovary.

Table 1 summarizes the results of this work and shows the increase in numbers of ripe eggs in the ovaries of progressively larger fish, a phenomenon that is widespread among fishes. Estimates from the counted aliquots give an average of 25,000 eggs per fish. A regression of numbers of eggs on size of fish was made by transposing the data into logarithms. The width of the 95% confidence belt shows that the mean egg count of the population at a given length may vary by about 6,000 eggs (Figure 4).

Garnaud (1957) determined the number of eggs in a nest of Dascyllus trimaculatus and stated that the number for the species varied between 20,000 and 25,000. He observed 17 spawnings by a single pair of these fish over a

TABLE 1. INCREASE IN NUMBERS OF RIPE OVARIAN EGGS WITH INCREASING LENGTH OF FISH.

Fork Length (mm.)	Estimated No. Eggs (thousands)
104	12.7
106	14.9
110	15.8
112	19.1
117	25.2
117	27.0
120	29.1
122	38.0
125	43.7

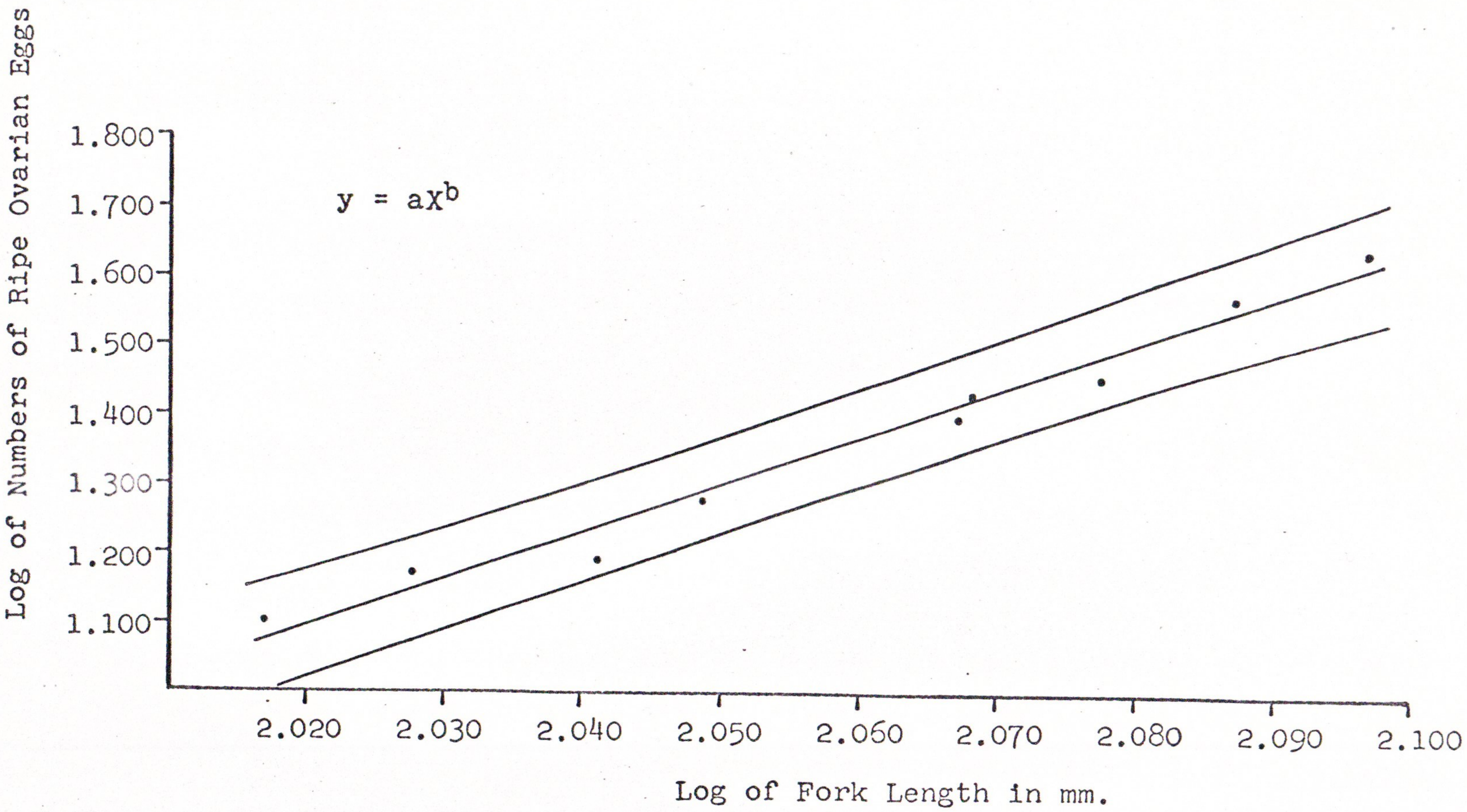


FIGURE 4. LOGARITHM OF NUMBERS OF MATURE OVARIAN EGGS ON·FISH LENGTH.

7 month period, placing the fecundity of the pair at about 350,000 to 400,000 eggs for a period of less than one year. Helfrich calculated an average of 21,000 spawnable eggs in the ovaries of the maomao, *Abudefduf abdominalis*, from a range of 9,400 to 41,000 eggs; however, he made no estimate of the number of spawnings made by single fish during one year.

If individual *Dascyllus albisella* spawn as frequently as *Dascyllus trimaculatus*, then these two species are probably among the most fecund in the family. Other pomacentrids, though spawning frequently, lay much smaller numbers of eggs. Garnaud (1951) observed an average of 880 eggs laid by two female *Amphiprion percula* (Lacepede), although numbers varied considerably. The fish spawned at least 10 times in one season, laying a total of about 8,800 eggs. Verwey (1930) determined that this species spawned only 200 - 300 eggs at one time and placed the yearly fecundity at about 5,000 eggs. He also observed broods of eggs spawned by *Amphiprion ephippium* (Bloch) to be about the same size as those of *Amphiprion percula*. Breder (1932) and Breder and Coates (1933) reported that the beau gregory, *Pomacentrus leucoris* Gilbert, deposited 400 - 500 eggs per spawning in the New York Aquarium.

The large numbers of eggs laid by *Dascyllus albisella* and *Dascyllus trimaculatus* may be related to their habit of making nests on open patches of bottom where they might be more vulnerable to predation. It is generally accepted that fish exhibiting parental care spawn fewer eggs than pelagic spawners that leave their eggs unattended (Hoar, 1957). Many of the pomacentrids including Amphiprion percula, Pomacentrus leucostictus Müller and Troschel, and Dascyllus reticulatus (Richardson) lay eggs in more sheltered locations. The smaller numbers of eggs produced by these species in relation to those produced by Dascyllus trimaculatus might be an example of the general tendency as it occurs within a single family.

2.2.4 Sex Ratio

The sex ratio for this species was determined by examining the gonads of a total of 723 fish that had been caught by trap, spear, and poison during 1959 and 1960. The majority of fish (456) were caught on the leeward side of Oahu and the remaining 267 came from traps set in the vicinity of the Coconut Island Marine Laboratory in Kaneohe Bay on the windward side during 1960.

The collections from the leeward side contained 44% males and 56% females (Table 2). Similarly, in Kaneohe Bay, females (67%) greatly outnumbered males (33%). Using the pooled data, it was found that the ratio differed significantly from a 50:50 ratio. A test of heterogeneity showed

TABLE 2. SEX RATIO OF DASCYLLUS ALBISELLA CAPTURED BY TRAP, SPEAR AND POISON AT WAIKIKI AND KANEOHE BAY DURING 1959 AND 1960.

Waikiki

Month	Total No. Sampled	Number Males	Number Females	Percent Females
1959				
May	57	26	31	54
June	38	15	23	61
July	45	24	21	47
August	36	12	24	67
September	40	16	24	60
October	18	11	7	39
November	20	14	6	30
December	32	10	22	69
1960				
January	39	18	21	54
February	22	13	9	41
March	49	21	28	57
April	60	22	38	63
Total	456	202	254	

Percent males = 44
Percent females = 56

Kaneohe Bay

1960				
April	48	21	27	56
May	110	28	82	74
June	75	31	44	59
July	34	10	24	71
Total	267	90	177	

Percent males = 33
Percent females = 67

a consistency within samples.

More data are needed before it can be definitely asserted whether or not an excess of females is present in the populations as a whole. The ratio might vary from place to place, although the reasons for such variation would be difficult to explain. Tester and Takata (1953) found a significantly greater number of male *Kuhlia sandvicensis* at Diamond Head, but also found a significantly greater number of females at Hauula Park on the opposite side of the island of Oahu. Helfrich (1958) found a greater number of male than female *Abudefduf abdominalis*, but he attributed the difference to selective sampling by traps employed in the capture of the fish. Randall (1955) found a greater number of males in trap-caught *Acanthurus sandvicensis* than in those captured by poison and spear.

2.3 NESTING

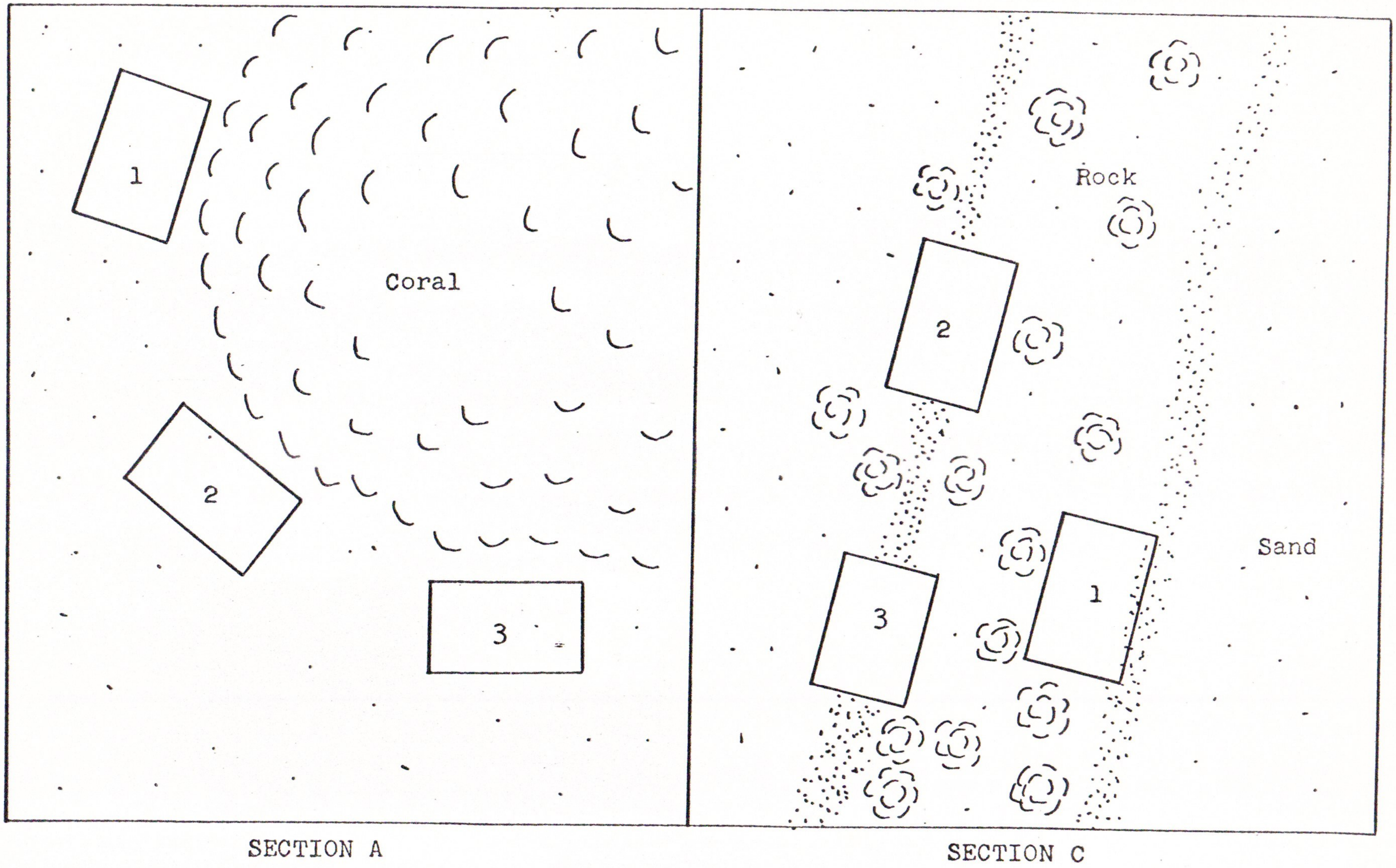
2.3.1 *Study Areas*

Studies on nesting *Dascyllus albisella* were carried out in waters extending in a seaward direction from the surge zone off Waikiki and Ala Moana Beach off the leeward side of Oahu. It was necessary to use a boat and diving apparatus because the study areas were located in water that ranged in depth from 45 - 70 feet.

Studies were carried out in two sections of this area (A and C, Figure 5). Section A was located about 3/4 mile offshore from the Ala Moana Yacht Harbor in water about 70 feet deep (see 3.2.4 for a description of the bottom). Three rectangular plots were marked off by placing bent iron bars at the corners to indicate the confines of the plots. Each plot was located on flat bottom with one of the two longest sides adjacent to a large mass of glomerate coral. Each plot measured about 30 x 15 feet, and enclosed an area of about 450 square feet.

Section C was located about 1/2 mile in a seaward direction from the Royal Hawaiian Hotel where the water was about 45 feet deep. The section consisted of a low ridge of flat rock bottom covered by patches of the glomerate coral, _Porites lobata_. The ridge ran in a northeast-southwest direction and sloped gently into a sandy bottom on the east side. On the west side, the slope leveled off as a hard bottom with a few dead glomerate, or massive, coral heads lying about. Three plots larger than those at section A (20 x 40 feet = 800 square feet) were marked off along the sides of the ridge where spawning seemed to be heaviest.

The plots at section C were marked off on June 10, 1959, and those at section A on July 10, 1959. During each observation, nests were found by first locating a male fish guarding the nest, and then searching for the nest itself.



SECTION A

SECTION C

Figure 5. Positions of experimental plots in which numbers of nests were observed at Waikiki during 1959 and 1960.

An attempt was made to count the number of nests in the plots twice each month, but difficulties involved in reaching the study area made it impossible to maintain a regular schedule of observation. However, two observations were made during most months of the year.

2.3.2 Description of Nests and Eggs

The nests of this species are difficult to distinguish from their surroundings. They are usually found on flat rock bottom but occasionally may cover an entire rock or a portion of one. They are generally rectangular in shape and are occasionally broken up into patches or strips if the bottom happens to be irregular. When first made, they are relatively conspicuous because of their greenish color in contrast to the dull whitish color of the bottom. The greenish color results from the removal of sediment from the nest by the male fish. The contrast is reduced and the nest becomes less conspicuous when filled with eggs.

The eggs average 0.85 mm. in length and 0.4 mm. in width. They are "typical" pomacentrid eggs, elliptical in shape, and are anchored to the substrate by a group of adhesive strands attached to one end. They are hyaline with very pale straw-colored yolks and are almost invisible on the bottom. They are distributed in the nests in dense patches of varied size. The patches may comprise only a few eggs and cover only a fraction of an inch, or they may comprise many eggs and cover several square inches. The patches as well as the individual eggs are often very close to each other, giving the nest a uniform appearance upon cursory examination.

No nests of this species were found in Kaneohe Bay, and the question arises whether or not fish actually spawn there. Much of the bottom is mud and would be unsuitable for spawning. The sloping sides of the reef flats are usually overgrown with algae and other sessile forms of marine life and likewise would not be suitable. Some areas of rock bottom with relatively few encrusting organisms were observed, but nests were not seen in these apparently suitable locations. In addition, the reproductive behavior associated with spawning activity was not seen. It appears that spawning either does not occur in the bay, or that it occurs in some locality that has not been seen.

It is likely that spawning occurs outside the bay in the deeper water. Since most spawning at Waikiki occurs at depths between 40 and 70 feet, it is possible that depth of water might influence this activity. Photographs taken by people diving for black coral in the deep waters off the windward side of Oahu show groups of large adult Dascyllus albisella as well as suitable kinds of bottom. The presence of nests on that side of the island would also explain the presence of juvenile Dascyllus albisella that occur on the reefs in the area. The presence of juveniles is an indication that nests are probably present in the vicinity. This problem can probably be settled by more field ovservation in both Kaneohe Bay and in offshore waters.

2.3.3 Frequency of Nesting

Observations of numbers of nests in the study plots were made over a period of one year beginning on June 10, 1959, and ending on May 23, 1960. Since it was recognized that fish spawned in nests that were located mostly on flat rock bottom, plots were set up in such locations in section C. Similar plots were set up in section A although a number of coral heads were present within their borders. Since old nests became inconspicuous within a day or two after being abandoned, it is obvious that all of the nests observed were recently made.

The number of nests counted in the two sections during 1959 and 1960 are summarized in Table 3 and the total numbers for each month are plotted in Figure 6. The data show a peak of nest building activity in June that declined slightly during July and declined rapidly during August. A rather definite increase that occurred in October was followed a month later by a decline until no activity was noted in January. Activity slowly increased during February and March and then rose quickly during May.

The data show a picture of spawning activity that is very similar to that shown by the ovary weight-body weight

		1959													1960								
	Plot No.	June 10	June 26	July 10	July 24	Aug. 7	Aug. 13	Sept. 11	Oct. 2	Oct. 16	Oct. 30	Nov. 8	Nov. 20	Dec. 2	Jan. 9	Feb. 3	Mar. 4	Mar. 20	Apr. 13	Apr. 21	May 8	May 23	Total
SECTION A	1			6	5	3	3	2	3	1	0	2	3	0	0	1	2	3	1	3	4	6	48
	2			7	4	4	3	5	0	0	0	1	3	0	0	0	0	1	1	2	5	3	39
	3			4	6	5	2	2	2	2	0	0	1	0	0	0	1	2	1	2	6	5	41
																						Total	127
SECTION C	1	9	9	8	5	3	2	4	2	3	0	0	0	0	0	1	2	0	3	2	7	5	65
	2	6	7	4	5	3	4	2	2	5	0	2	0	0	0	1	3	0	1	3	6	8	63
	3	8	7	10	10	4	3	1	4	3	0	0	3	3	0	0	0	0	2	4	4	6	72
																						Total	200

TABLE 3. NUMBERS OF DASCYLLUS ALBISELLA NESTS OBSERVED IN SECTIONS A AND C AT WAIKIKI DURING 1959 AND 1960.

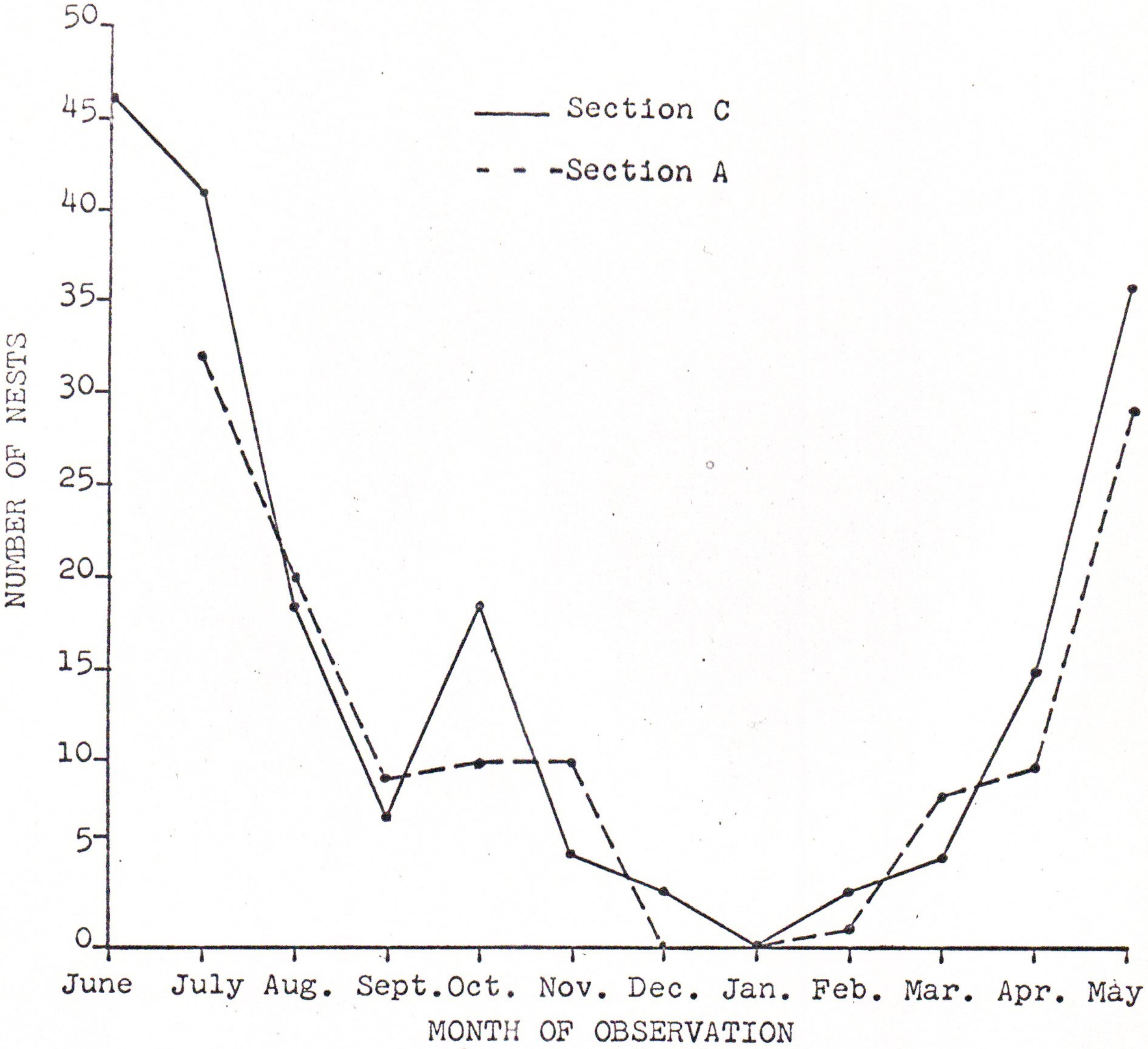


Figure 6. Seasonal fluctuations in numbers of nests observed at Waikiki during 1959 and 1960.

ratios of Figure 1. The peaks of reproductive activity both occur in June although the data on nesting show a more rapid decline of activity in August than do the ovary data. Nest building activity showed a slower build-up during February, March and April than the ovary data do; the difference however may have been due to the fact that the data were taken in different years.

2.3.4 Incubation Period

An unusual opportunity was presented for studying the nesting cycle in detail. On August 16, 1960, 11 nests without eggs were observed at section C, and 5 were observed at section A. Four nests at section A were selected for detailed study and 7 others were spot-checked to determine how long the eggs remained. Observations were made daily for the next six days during the late afternoon. Temperatures were recorded during each of the observations.

On October 17, the outlines of the four nests were traced on a piece of plastic so that any future change in size could be noted. Two of the nests were full of eggs completely covering the surfaces within their borders. One had been abandoned and was already almost completely covered by silt. The fourth nest contained eggs which were still being guarded by the male fish. A spot-check of the other nests revealed that 5 had been abandoned and the other 2 contained eggs.

On October 18, the nests had not enlarged in size and did not appear to contain any additional numbers of eggs. However, the nest that was empty the previous day contained eggs. The nests were again measured, but proved to have the same dimensions as the previous day.

On October 19, no change was noted in the areas of the nests, and the number of eggs was apparently the same. One of the nests had a small patch of opaque eggs that were presumed to be dead.

The patch of opaque eggs was not seen on October 20 and a bare patch was apparent in the nest where they had been. One of the nests had been enlarged by about 30 square inches, but the new section had not been thoroughly cleaned and contained no eggs.

On October 21, the 2 nests that had first contained eggs were empty and the guarding males had left them; the same was true for the other 2 nests that had been spot-checked. The nest that had received eggs on October 18 still contained them and the male was present. This nest was vacant the next day on October 22 when the final check was made. The period of time from the initial observation of the eggs until they hatched extended over a 4 day period.

It is difficult to compare the incubation period of Dascyllus albisella with that of other pomacentrids since most of the information on the latter is based on laboratory studies. The incubation period for Abudefduf abdominalis was 6 days at 24.5° C. (Helfrich, 1958), which corresponded with that of its close relative Abudefduf saxatalis (Shaw, 1955). Brinley (1939) reported that the eggs of Pomacentrus leucostictus hatched in five days at temperatures between 28° and 31° C. The shorter incubation time is similar to that of Dascyllus albisella which occurred at temperatures ranging from 26.2° to 27.5° C. The temperatures during the early fall are usually about 2 degrees higher than in early summer which might shorten the incubation period. However, Garnaud (1957) stated that eggs of Dascyllus trimaculatus required 4 days to incubate in aquaria at temperatures of about 24° C., a figure he mentioned as being optimum for retaining the fish. He further stated that hatching began in the morning and lasted at least throughout the day.

It has been shown in other pomacentrids that more than one female fish may contribute eggs to a single nest (Brinley, 1939; Helfrich, 1958). To study this possibility in Dascyllus albisella, ten nests were chosen at random in section A at Waikiki. The contours of the nests were drawn in the field by tracing them on a sheet of plastic held close over the surface of the nests and the number of square inches within the nest was calculated. Four 1-inch square areas within each nest were scraped and the number of eggs was counted. This number of eggs, when multiplied by the total area of the nest, gave an estimate of the total number of eggs they contained, and the 95% confidence interval for each of the nests (Table 4). The average of 25,000 eggs per fish calculated from ovary data in Table 1 may be applied to the estimated numbers of eggs in nests to give an approximate estimate of the possible number of fish that might have contributed.

Table 4 summarizes the results of this investigation and shows that numbers of eggs contained in the nests are sufficiently large in comparison with numbers of ripe eggs found in ovaries to show that more than one fish probably laid in some of the nests. The actual number contributing to a single nest, however, is uncertain because the size of the fish contributing was unknown.

2.4 REPRODUCTIVE BEHAVIOR

2.4.1 Nuptial Coloration

At the time when male fish have established a nest site and are engaged in courtship activity, their coloration becomes brighter than usual. The entire body of the fish is white and only the caudal, anal and pelvic fins retain the black coloration. The dorsal fin, which is usually black, also becomes white except for a black strip along

Nest Measure in Inches	Area in Sq. In.	Est. No. Eggs in Thousands	Confidence Interval 0.05
12.0 x 10.0	120.0	125.6	103.0-148.0
10.5 x 8.5	89.3	82.6	73.1- 92.1
9.6 x 6.1	58.6	55.3	47.7- 62.9
8.3 x 6.5	53.9	43.6	38.2- 49.2
9.0 x 5.5	49.5	46.7	40.3- 53.2
12.0 x 4.0	48.0	47.9	41.7- 54.0
12.0 x 4.0	48.0	45.1	37.3- 52.9
10.0 x 4.3	43.0	36.5	31.5- 41.4
7.5 x 5.5	41.3	33.7	26.3- 40.9
7.1 x 5.6	39.8	35.9	32.6- 39.2

Avg. nest = 52.4 sq. in. (excluding the data for the largest nest.)
Avg. no. spawnable eggs / fish = 25,000

TABLE 4. ESTIMATED NUMBERS OF EGGS IN NESTS OF VARIOUS SIZES.

its free edge. At times the fins have an amber tint that may be seen when the fish turn in various directions. This fin color, however, is occasionally seen in feeding fish and may seem to be more pronounced in breeding males only because of their greater activity during courtship.

As in many fishes, characteristic color changes occur in male pomacentrids during the reproductive season. Longley and Hildebrand (1941) briefly describe the breeding coloration of *Pomacentrus leucostictus*, which changes from a bluish-black to a uniform dusky yellow-olive or may assume a yellow color over only the dorsal surface. They also state that *Chromis insolatus* (Cuvier and Valenciennes) displays spawning coloration. Helfrich (1958) observed that the normal black stripes of male *Abudefduf abdominalis*, when, breeding, became a pale gray and were often invisible whereas the normal brassy green to yellow base color was transformed into a pale blue. Part of the color manifestation of at least some pomacentrids occurs as an enhancement of already existing colors such as was seen in the brighter white appearance of *Dascyllus albisella* and in the yellow tail of *Stegastes chrysurus* (Cuvier and Valenciennes) described by Longley and Hildebrand (op. cit.) as being bright yellow in a fish that was guarding a nest.

2.4.2 Courtship

Male fish normally hover several feet over the nest site, moving closer when other fish intrude into their established territories. While hovering, they feed on planktonic organisms which drift past the nest. Apart from defending the territory against intruders, they occasionally fan the eggs, or engage in the nuptial display which serves to attract females to the nest. The display becomes most intense when other Dascyllus albisella approach the territory, but is also carried out when fish are not in the immediate area.

At the beginning of a display, the male swims upward at a steep angle using only its pectoral fins for locomotion. Quite suddenly, it turns on its side and darts toward the bottom in a curving half loop, at the bottom of which it turns upright and sometimes immediately repeats the performance. The curving loop is accomplished by an exaggerated anguiliform motion which, along with their white color, makes them very conspicuous to an observer and presumably also to other fish of the same species. If the performance is repeated continuously, the exaggerated swimming motion is also used for the upward phase of the display and the fish accomplishes a complete loop. A series of loops may be performed in rapid sequence but the fish usually rights itself after each loop.

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The display is apparently directed toward a particular fish as activity often increases or decreases with the approach or withdrawal of a particular individual. If the "courted" fish swims in the general direction of the nest, the male discontinues his display and swims in front of her, and leads her to the nest site. If the female begins to swim away from the nest, the male resumes his display until she either turns again toward the nest or withdraws completely. The fact that some Dascyllus albisella are chased from a territory while others are "courted" indicates that the displaying male can distinguish between sexes or perhaps between gravid and non-gravid females.

At the approach of a feeding aggregation of fish (Section 2.7), a displaying male may leave its nest and swim ten or twelve feet up from the bottom to join them and to perform his display. Here he sometimes encounters competition from other displaying males that have temporarily joined the aggregation from nearby territories. Three or four males may sometimes be seen displaying within a single feeding aggregation. However, not all displaying males in such aggregations are territory holders. Those with territories return to them, sometimes accompanied by a female, whereas the others remain with the aggregation as it moves along. The fact that some fish carry out this activity while not occupying a territory indicates a high level of motivation for the display which probably takes place in response to the stimulation from a nearby female or from a

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displaying male, although an external "sign" stimulus may not be necessary (Tinbergen, 1951).

When the male and female arrive at the nest, the two fish may begin to spawn immediately. In most cases they tilt sideways with their abdomens close or touching in a V-shaped arrangement. In this position, they circle slowly almost touching the surface of the nest, the female laying eggs and the male fertilizing them while shivering noticeably at times. This activity may cease for short periods during which the fish engage in chasing each other over the surface of the nest. Later during spawning, the female may continue to lay eggs in one portion of the nest while the male continues to fertilize in another.

Spawning ceases when the female swims away from the nest. The male neither pursues her nor continues the nuptial dance, but continues to spend some minutes fertilizing the eggs, picking at the nest with its mouth, or dashing around over the surface. It gradually ceases this activity, again taking up a station close to the nest where it spends its time driving away intruders or fanning the eggs. After the nest is full of eggs the male becomes more aggressive and persistent in its attacks on other fish as well as on an observer. Approaching fish are intercepted farther from the nest than previously and the dashes of the male are sometimes accompanied by audible grunting noises.

The male spends a considerable amount of time fanning the eggs and picking at the nest, apparently removing dead eggs and perhaps debris not removed by fanning. When engaged in this activity the fish swims on its side, but with the longitudinal axis of the body tilted slightly upward. From this position, a vigorous swimming motion of the body coupled with a vigorous backing motion by the pectoral fins produces a strong current of water that washes over the nest removing debris and aerating the eggs. The fish moves slowly across the nest while performing this activity, occasionally dashing quickly to another part of the nest where the activity is resumed. Occasionally, several fish on adjacent nests have been seen fanning the eggs simultaneously, indicating mutual visual stimulation. A group effort such as this might conceivably result in more frequent fanning which would lead to better aeration and removal of foreign material and thus increase the possibility of survival of the eggs.

The nesting activity of *Dascyllus albisella* follows a similar pattern to that shown by other pomacentrids. Whereas other species may prepare the nest over a period of several days (Garnaud, 1957), *Dascyllus albisella* like *Dascyllus trimaculatus* takes only a short time. However, *Dascyllus albisella* spends considerable time fanning loose materials from the nesting site before eggs are deposited, whereas *Dascyllus trimaculatus* does not (Garnaud, op. cit.).

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The body of the former species becomes bright white; and the latter species turns pale, assuming a bluish or greenish tinge. The nuptial dance of the two species appears to be the same and in both, the male performs in front of the female and leads her to the nest.

The nuptial dance of *Dascyllus albisella* is similar to that of other species in the genus that were observed by the author at Eniwetok Atoll. The similarity with *Dascyllus trimaculatus* has already been noted. *Dascyllus reticulatus* (Rüppell) and *Dascyllus aruanus* (Linnaeus) both displayed essentially the same type of activity, although in both cases the looping motion was less vigorous. In making the downward half of the loop, *Dascyllus aruanus* appeared to turn on its side at a less steep angle than the three other species. In all species, the accentuated swimming motion by which the fish carried out the characteristic maneuver was evident.

The display exhibited by *Dascyllus albisella* appeared to be much the same as that which Abel (1961) described for *Chromis chromis* Linnaeus and called the "signalsprung" or signal jump. The fish performed a similar looping motion at the nest site apparently in response to the presence of other fish of the same species that swam above the nest site. Like *Dascyllus albisella*, the females occasionally deserted this aggregation and moved to the bottom to spawn

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in the nests. In *chromis chromis*, the nests were jointly defended by the males rather than individually defended as in *Dascyllus albisella*. The males of both *Dascyllus albisella* and *Chromis chromis* no longer engaged in nuptial display after the females had left the nesting area.

The nuptial dance of *Abudefduf abdominalis* (Helfrich, 1958) is somewhat different from that of *Dascyllus albisella*. Although *Abudefduf abdominalis* performs a barrel-roll type of activity like that of the species discussed above, it appears to incorporate other maneuvers such as "zigzag swimming", as well as assuming a vertical position in which it more or less stands on its head. Longley and Hildebrand (1941) gave a brief description of the nuptial dance of *Pomacentrus leucostictus* that is similar to that of *Abudefduf abdominalis*.

In all pomacentrids that have been studied, the nests are guarded aggressively. In most species the male fish apparently guards and fans the eggs after they are deposited in the nest. Breder and Coates (1933), however, noted that both male and female *Pomacentrus leucoris* attended the eggs that were laid in the New York Aquarium. Gohar (1948) observed that only one *Amphiprion bicinctus* Rüppell attended a clutch of eggs laid at the aquarium in the marine biological station at Ghardaqa on the Red Sea. The situation in the field, however, is obscure since *Amphiprion* sp. lay

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their eggs close to anemones, and it is uncertain whether they are defending the nest or the anemone.

2.5 OBSERVATIONS ON LARVAE

Dascyllus albisella eggs are easily hatched in the laboratory at room temperature and with good aeration. A number of hatchings were made in order to compare the larvae with those of *Abudefduf abdominalis* (Helfrich, 1958). It is hoped that the comparison might be an aid to others in distinguishing between the larval forms of the species.

Newly hatched larvae of *Dascyllus albisella* are about 2.5 mm. in length and have a filiform appearance and a prominent yolk sac. The yolk sac is oval-shaped instead of triangular as in *Abudefduf abdominalis*. At the time of hatching, they have a series of yellow patches which may merge into a yellow line, running the length of the trunk on both the dorsal and the ventral sides. It is believed that this consists of accumulated fatty material since it disappears within a day or two after hatching. This material may be characteristic of the species for it was seen in three different broods of newly hatched larvae and it has not been reported for *Abudefduf abdominalis*.

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At the time of hatching, the eye of *Dascyllus albisella* is almost completely unpigmented except for a very fine accumulation of dark particles on the ventral side. The pupil is at first colorless, but appears black on the second day. This change is associated with the further development of pigmentation within the eyeball, which also becomes black. Apparently the eye of *Abudefduf abdominalis* is in a later stage of development at hatching, as the pupil appears black at that time.

The behavior of the larvae undergoes a rapid change within the first few days after hatching. At hatching, they are quite helpless and float passively in the water. Such movements as occur do not produce oriented motion. At this time they may easily be caught by scooping them into a beaker or cup. By the end of the first day, oriented movement occurs over a distance of two or more inches. In consequence, they are much harder to catch as they will dart away from the beaker or cup.

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During the second day, they appear to dart at particular objects in the water and also at each other. Larvae that are approached by others dart away as if in fright. It appears that these actions are the first manifestations of responses associated with feeding and escape from enemies. On the third day, the larvae strike at minute objects on the bottom and lower sides of the containers. This behavior is accompanied by jaw movements, which suggest that the fish are trying to ingest objects. However, attempts at feeding them failed.

Soon after hatching, the larvae collect at the surface or in the upper half of the water column. It is not certain whether they arrive there as a result of their own activity or as a result of positive buoyancy. After a day or so when they become better oriented, they dart toward the surface of the water and remain at or near the surface while it is illuminated by overhead lights. Garnaud (1957) observed similar activity in *Dascyllus trimaculatus* larvae and concluded that the larvae were pelagic, a conclusion that also seem justified for *Dascyllus albisella*.

2.6 GROWTH RATE

The difficulties in obtaining juvenile *Dascyllus albisella* in quantity have been dealt with under the section on length frequency of juveniles (Section 3.3). Determining growth rates under natural conditions by tracing the progression of modal groups in length frequency distributions in time series was not possible with this species. Therefore, a number of attempts were made to determine the growth rate in other ways.

Four cages measuring 4 x 4 feet square were constructed from galvanized wire with 1 inch mesh size. They were placed in an old excavation in the fringing reef about six

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feet deep located on the east side of Coconut Island at the end near the entrance to the channel leading into the lagoon. One living coral head was placed in each of the cages on a platform raised off the bottom, and 10 juvenile Dascyllus albisella were introduced into each. It was thought that the fish would remain close to the protection of the coral head and that the presence of the cage around them would act as a further stimulus causing them to remain associated with the coral. However, within two days all but two of the fish had disappeared. Both of the fish had developed a very pale coloration and a translucent snout. Both disappeared within a few days.

The cages were restocked with more fish, but some of these disappeared the next day and all but three had left by the end of one week. The three remaining fish had developed the same appearance as those in the previous attempt. Four of the fish, recognizable because of the translucent snout, were found with a group of wild fish in a large coral head located about six feet from one of the cages. Both the wire in the cages and the coral heads had become silted. The method was abandoned in view of these difficulties.

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An attempt was made to establish measured juveniles in coral heads that were placed in more or less natural positions in characteristic habitats. On November 10, 1959, 5 live coral heads, were transported from Coconut Island to the south side of Kewalo Basin on the leeward side of Oahu where they were placed on the bottom in the dock area, and five juveniles were introduced into each. By the time that all of the fish had been released, a check of the results showed that most of the fish in two of the heads had already been eaten by trumpet fish (Aulostomidae), which were abundant in the vicinity. The predators were hovering around the coral heads in their attempts to capture the remainder of the fish. After two days, one coral head still contained five fish, three heads were empty, and one had apparently been removed by someone.

On November 26, 4 fish that remained in one of the coral heads were captured and their fork lengths were measured. An attempt was made again to catch them on December 10, but the fish deserted the coral head and hid among the rocks beneath it. Surprisingly, they remained within the head on December 15 when they were again captured and measured. After this, attempts to capture them by raising the coral head failed as did an attempt to poison them. The experiment was abandoned.

Table 5 shows the lengths of the fish over the 35 day observation period during which they increased in mean length from 18.9 to 23.9 mm. This corresponds to a mean growth rate of 0. 14 mm. per day.

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TABLE 5

MEASUREMENTS OF THE FORK LENGTHS OF JUVENILE DASCYLLUS ALBISELLA IN ONE EXPERIMENTAL CORAL HEAD AT KEWALO BASIN DURING NOVEMBER AND DECEMBER, 1959.

	Fork Length in mm.		
	Nov. 10	Nov. 26	Dec. 15
	15.2	16.2	18.0
	16.7	20.9	23.0
	19.0	23.8	26.7
	20.0	25.5	27.0
	24.0		
Mean Length	18.9	21.4	23.9

A similar experiment was started at Coconut Island on November 14. Three living coral heads were mounted on wooden platforms and placed on stakes driven into the bottom of the lagoon in front of the laboratory. One was placed close to the bank near the southeast boat landing and the other two were close to the bank on the opposite side of the lagoon, one being near the entrance channel and the other near a mangrove patch farther inside the lagoon. Six measured fish were introduced into each of the coral heads which were removable so that fish could be shaken out and periodically remeasured.

At the end of the first two-week period, the fish had all disappeared from the coral head near the entrance to the lagoon, and four remained in each of the other two heads. Because of this initial loss, the measurements recorded on November 29 were used as the first recorded lengths of the remaining fish.

Growth was followed for a 14 week period, after which the study was terminated because of a three month absence of the investigator. The average lengths of the four fish in each of the two coral heads are given in Table 6 and plotted in Figure 7. Growth followed a linear pattern with no significant curvilinear component. The increase in length during the 14 week period was 16.8 mm. with an average increase of 1.2 mm. per week or 0.17 mm. per day (the latter

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TABLE 6. GROWTH RATE OF DASCYLLUS ALBISELLA IN LAGOON AT COCONUT ISLAND MARINE LABORATORY DURING 1959 AND 1960.

Date of Observation	Coral Head #1	Coral Head #2	Number Fish in Each Coral Head
1959 Nov. 29	13.3 mm.	14.2 mm.	4
Dec. 13	16.4	17.8	4
Dec. 27	19.4	19.9	4
1960 Jan. 10	21.4	22.1	4
Jan. 24	23.6	24.5	4
Feb. 7	25.6	26.3	4
Feb. 21	27.5	28.4	4
March 6	30.0	31.1	4

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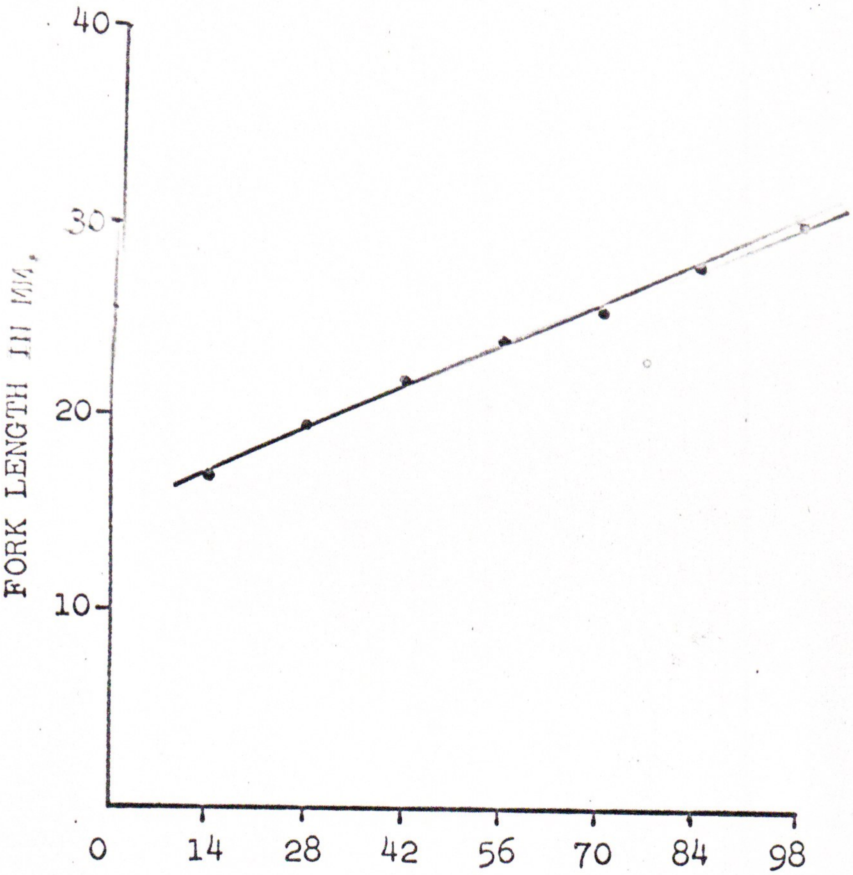

Figure 7. Average growth rate of juvenile Dascyllus albisella from November 1959 to March 1960 in the lagoon at the Coconut Island Marine Laboratory.

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figure is a daily average and is not based on the slope of the line).

One additional observation of growth rate under natural conditions is available. A large number of juvenile fish appeared in experimental coral heads at Waikiki on or about June 22, 1961 (Section 3.12.1). This group of fish together with those that appeared late were captured on July 30. The length frequency distributions (Figure 35) show two distinct modal groups, one constituting recently arrived fish and the other, those which had grown in size since their arrival on or about June 22. If the average size of juveniles (14.7 mm.) at the time they first enter coral heads is used as the initial size of the latter group (17.1 mm.), it may be calculated that the fish have grown 2.4 mm. over a period of 38 days. The average growth per day, 0.06 mm., is considerably less than that of 0.18 mm. for the experimental fish in the lagoon at Coconut Island. One might expect the growth rate of the Waikiki fish to be greater rather than less than that of the Kaneohe Bay fish for the observations were made in the summer in the former and in the winter for the latter, and there is about a 5 degree difference in temperature that could be expected to influence growth. The discrepancy may be due to the rough nature of the Waikiki data. Another very likely explanation is that growth rate was depressed at the Waikiki

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coral heads because of intense competition for food. The coral head was populated by a very large aggregation of fish.

The information concerning the growth rate of juvenile *Dascyllus albisella* may be compared with observations made by Helfrich (1958) on the growth of *Abudefduf abdominalis*. In comparing the progression of length frequency modes with time, he found that in February and March of 1957, fish grew an average of 0.13 mm. per day in comparison to an average of 0.17 mm. per day for juvenile *Dascyllus albisella* that were slightly larger in size. Thus, the growth rate of juveniles is similar in order of magnitude, but may be slightly higher in *Dascyllus albisella*. If the two species also grow at similar rates during the summer when presumably the rate is comparable, then it is possible that juvenile *Dascyllus albisella* could reach sexual maturity in about one year.

The sampling data are inadequate for drawing broad conclusions on the growth rate of *Dascyllus albisella*. It is apparent from its behavior that growth rate could vary widely depending on the location of the habitat. Observations of the feeding behavior of fish in the lagoon at Coconut Island, where water flow is slight, show that they feed much less actively than in Kaneohe Bay where a much greater water flow is encountered. This suggests that food

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is less available in the former locality and that the growth rate should be slower. Again, as indicated by the Waikiki data, the intense competition for food in overpopulated coral heads may produce a slow rate of growth, thus further complicating the problem of evaluating the growth of fish that remain in a very restricted location. Since temperature was not studied in detail, its effects on growth cannot be evaluated.

2.7 FOOD AND FEEDING

2.7.1 Feeding Behavior

Dascyllus albisella feeds almost exclusively on planktonic organisms. Juveniles remain very close to coral heads on the bottom, and feed exclusively on plankters that drift past them, thus depending on water movements for their food. Adults are not as intimately associated with coral and move around within a restricted area which might be extensive if the bottom offers sufficient cover.

Adult fish off Waikiki differ in feeding behavior from those in Kaneohe Bay. In the former area, fish form feeding aggregations of from a few to hundreds of individuals, which are separated from each other by several feet or more, and which move independently in various directions while feeding. Individuals move rather slowly and deliberately as they feed, picking small organisms from the water;

They do not exhibit the quick darting motions of the juveniles. Although the organization of the school is loose, an integrity exists and fish move slowly along as a unit. The individuals of an aggregation congregate in a stratum of water that may vary in thickness from 10 to 20 or more feet.

Because of turbidity, it was difficult to make observations on feeding in Kaneohe Bay. The few groups of adults that have been seen did not ascend more than a few feet off the bottom in their feeding activity. The aggregations maintained a much closer relationship with the bottom than those at Waikiki and the former were much wilder. The readiness with which they took flight suggests that they were in a more excited state. Fish in such a state of agitation might not have spent much time feeding as those that inhabited clear water off Waikiki. In addition, their behavior in staying close to the bottom probably restricted the amount of water available to them from which to catch plankters.

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Feeding aggregations such as those seen in adult Dascyllus albisella are characteristic of other pomacentrids. In Hawaii, Chromis ovalis and Abudefduf abdominalis fed in this manner and Chromis verator, Chromis vanderbilti and Chromis leucoris Gilbert did so to a lesser extent. Limbaugh (ms.) observed that off the coast of California, Chromis punctipennis (Cooper) gathered in large aggregations while feeding on plankton that drifted in on the currents. Abel (1961) observed that Chromis chromis Linnaeus gathered in swarms over the nesting area where there can be little doubt that the fish fed on the plankton when not engaged in [illegible]

This type of feeding behavior appeared to a lesser degree in the behavior of Dascyllus trimaculatus and Dascyllus reticulatus at Eniwetok Atoll. There the fish did not wander over relatively large areas, but were restricted to a particular coral head or knoll. Although Dascyllus trimaculatus fed up to 15 or 20 feet from shelter, they always returned to a certain area when pursued. Dascyllus reticulatus fed only up to about 10 feet from shelter and Dascyllus aruanus rarely departed more than one or two feet from a coral head. It is probable that the abundance of large predatory species at Eniwetok Atoll kept the fish more closely confined to shelter. On two occasions, the appearance of carrangid fishes resulted in immediate withdrawal of aggregations of Dascyllus reticulatus into their coral heads.

2.7.2 Food

The food of Dascyllus albisella is much like that of other plankton feeding species and is comprised of many different kinds of planktonic organisms. The stomach

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contents of 90 fish caught at different times and places were identified and measured for volume in a graduated cylinder. The results were summarized by calculating the percentage of various organisms contained in the stomachs of fishes that were arranged into three size groups (Table 7).

Copepods were the most abundant organisms found in stomachs and fragments of polychaete worms, larvaceans, miscellaneous crustacea and adult shrimp-like crustaceans were also well represented. Copepods also formed the greatest volume in stomach contents of the smaller fish, whereas larvaceans and shrimp-like crustaceans formed the greatest volume in the larger fish. A discussion of relationships between organisms found in the stomachs of juveniles and selectivity in feeding appears in Section 3.8.

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2.8 MIGRATION

Large concentrations of adult *Dascyllus albisella* live in the immediate vicinity of patches of glomerate corals in the waters of Waikiki on the leeward side of Oahu. The coral beds serve as cover for the fish, and range in area from a few square feet to an acre or more. The patches of coral occur on very flat rock bottom and may be either far from other similar patches, adjacent to them or separated by varying distances. Figure 8 is a photograph taken at a depth of 70 feet off Waikiki showing a fairly large

Figure 8. Habitat of adult Dascyllus albisella showing Porites lobata coral head cover and flat bottom where nesting occurs.

glomerate head of *Porites lobata* with two adult *Dascyllus albisella* hovering over it. To the right of the patch can be seen a typical section of flat rock bottom on which fish make their nests and lay their eggs.

In many cases two patches of coral that are relatively close to each other have aggregations of fish that appear to be associated with only one or the other of the patches. When feeding, an aggregation travels over the bed of coral, which may be fairly extensive, and does not appear to depart more than 20 or 30 feet beyond the periphery.

A situation was encountered at section A off Waikiki in which three patches of coral were located at varying distances from each other (Figure 9). The two large patches (I and III), had aggregations of fish estimated at between 300 - 400 individuals, which were never seen to stray more than about 20 feet in any direction beyond the coral. The smaller patch (II) had only about 40 fish which appeared to remain in the one spot. At attempt was made to obtain information on possible movements of fish between these three locations.

Since *Dascyllus albisella* do not readily enter commercial traps off the Waikiki area, a special trap was designed to catch the fish. The trap was 3 feet square with the four vertical edges made from 1/2 inch pipe. The top and bottom were made of transparent sheet plastic, but the

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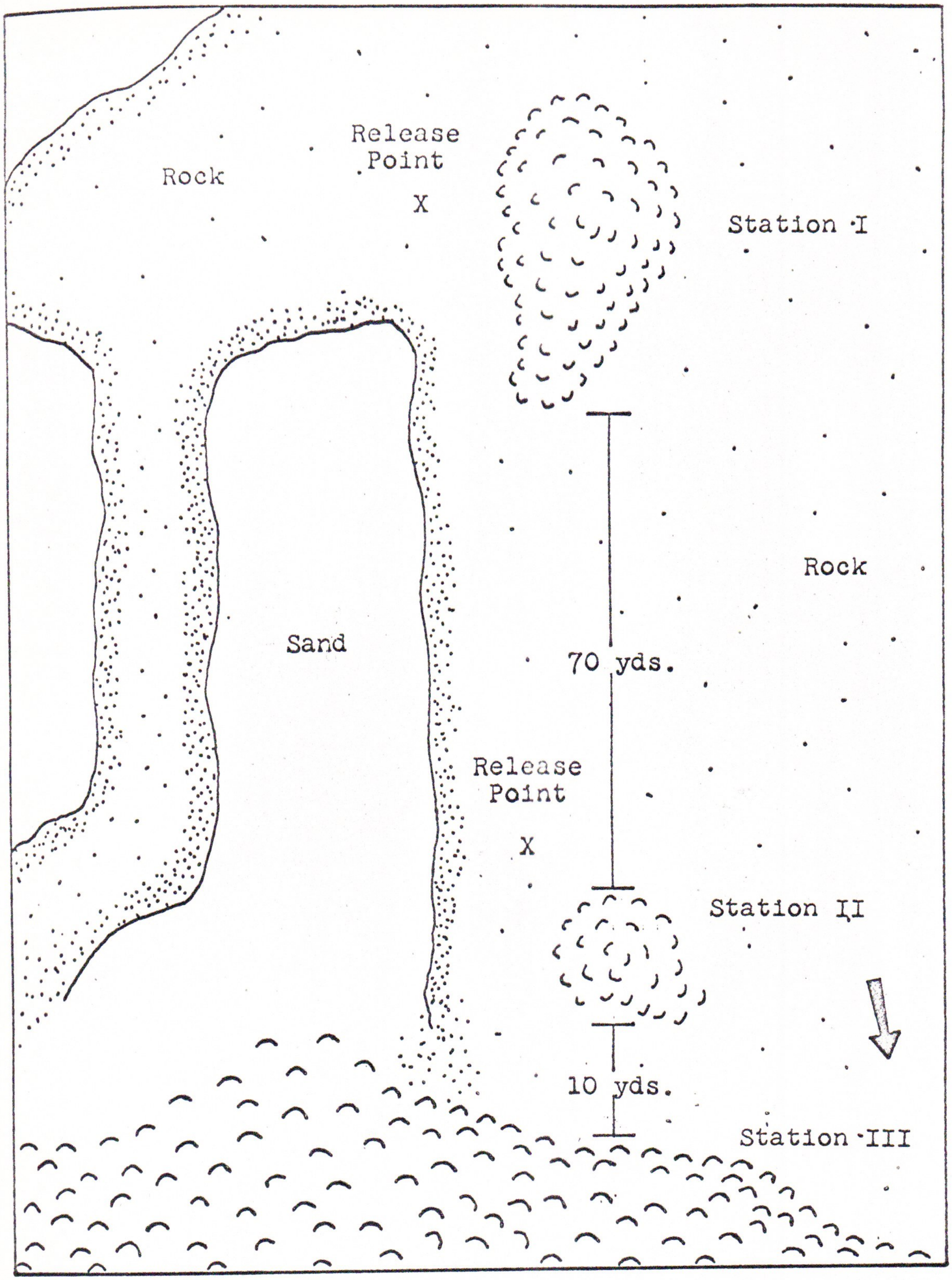

Figure 9. Position of stations and release points used in studies on migration of adult *Dascyllus albisella*.

sides were open. A square metal frame with an attached net was designed to fold down flush with the bottom. Lengths of rubber tubing were attached to each of the four corners of the frame and to the tops of the pipe stanchions above them. Pulling the frame and net down to the bottom of the trap opened the sides of the trap and put a strain on the four lengths of tubing. When a trigger was released, the net was pulled upward by the stretched tubing thus closing the sides of the trap. Adult fish quickly gathered in the open trap when sea urchins were crushed or when hamburger was released. When a sufficient number had entered, the trap was sprung and they were caught.

The trap was fairly efficient, but was difficult to use from a small boat and required the efforts of at least two people. Difficulty was experienced in getting it out of the water, particularly when the surface was choppy or a slight current was running. Even under ideal conditions, only two sets could be made during one day. Trapped fish had to be raised slowly to the surface to allow them to decompress; this process required more than an hour of work. After tagging, fish were taken immediately to the bottom and released. In spite of the difficulties, a number of successful catches and taggings were made.

Since observations of tagged fish were to be made visually underwater, a type of tag was employed that

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streamed back over the dorsal side of the fish for greater visibility. This consisted of a 6 inch piece of yellow spaghetti nylon tubing inserted through the back of the fish below the soft dorsal fin. The ends were brought around to form a loop and were clipped together. The tag was treated with bacitracin ointment in an attempt to reduce infection of the wound.

About four days after release many tagged fish had developed raw areas about ½ inch in diameter around the tag wound and the holes through which the tags were inserted had increased to about twice their original size, thus loosening the tags. After about a week, the tags on a few fish had worked through the enlarged area of deteriorating flesh and were lost. Some fish which had shed their tags survived and the wounds healed within five weeks after release, leaving a longitudinal scar along the postero-dorsal side.

The behavior of tagged fish after release may be of interest to others who may use this method with other species. Upon release, a tagged fish would swim away in an unsteady fashion and would sometimes swim a straight course that seemed to be independent of the presence of other fish. After traveling 50 or 60 feet, it would turn and then join other fish in the vicinity, which showed no noticeable reaction toward it. The locomotory behavior was altered.

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A tagged fish swam with greater effort than an untagged fish and used its trunk musculature as well as its pectoral fins.

The tagged fish tended to remain together immediately upon release and thereafter for a period up to one week after release. At times as many as 5 tagged fish were seen together in the feeding aggregation and all were behaving normally. The knowledge that some tagged fish remained closer to each other than to other fish in the feeding aggregation is important to programs designed to sample the *Dascyllus albisella* stock by utilizing this method of tagging. It is apparent that the failure of tagged fish to disperse randomly throughout the stock might lead to erroneus conclusions concerning the population.

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Tagged as well as untagged fish were also seen among the coral on the bottom. However, it was apparent that there were proportionally more tagged than untagged fish in such places. This tendency of tagged fish to remain close to the bottom rather than in the feeding aggregation might also lead to non-random sampling.

Three groups totaling 38 fish were caught and tagged over a period of 10 days (Table 8). It had originally been decided to tag separate batches of fish with different colored tubing, but since the catches were small, the same yellow color was used and the three groups were considered

TABLE 8. NUMBERS OF TAGGED FISH REMAINING AT VARIOUS STATIONS OFF WAIKIKI DURING 1959 AND 1960.

	Number Tagged Fish Observed			Percent Tagged Fish Observed
	Station			
	I	II	III	
Nov. 15, 1959	12	5	0	45
Nov. 22, 1959	16	8	1	66
Dec. 6, 1959	10	8	1	50
Dec. 20, 1959	8	8	1	45
Jan. 10, 1960	8	7	no obs.	39
Jan. 31, 1960	3	2	1	17
Feb. 14, 1960	0	0	1	3

Date of Tagging	Number of Fish Tagged
Nov. 1, 1959	7
Nov. 7, 1959	14
Nov. 11, 1959	17
TOTAL	38

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